PB-221 545

REMOVAL OF OIL FROM UNDER PIERS

Bernard Katz

Edison Water Quality Research Laboratories

Prepared for:

Environmental Protection Agency

February 1973

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

EPA-R2-73-116
FEBRUARY 1973

Environmental Protection Technology Series

W73-11438

PB 221 545

Removal of Oil from under Piers

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

Office of Research and Monitoring
U.S. Environmental Protection Agency
Washington, D.C. 20460

34

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Monitoring, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

11

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No. | 2. | 3. Accession No. W 73-11438

4. Title: REMOVAL OF OIL FROM UNDER PIERS,

5. Report Date
6.
8. Performing Organization Report No.

7. Author(s): Katz, Bernard

10. Project: EPA Project 15080 FVP

9. Organization: ~~Alpine Geophysical Associates, Inc. under contract to~~ New York City Fire Department, N.Y.

11. Contract/Grant No.

13. Type of Report and Period Covered

~~12. Sponsoring Organization Environmental Protection Agency, W.Q.O.~~

15. Supplementary Notes: Environmental Protection Agency, Technology Series report number, EPA-R2-73-116, February 1973. 29p, 3 fig, 2 ref

16. Abstract: While this report deals primarily with methods of extracting oil from under piers, it is recognized that simple extraction is not enough, and that the oil should also be removed from the environment. Therefore, considerable attention has been paid to driving the oil out in such a way that it can be picked up. The primary means of extraction are by the establishment of artificial currents under the contaminated pier, and a number of methods are suggested to cope with various types of pier substructure.

Some other possible approaches, not involving flushing by artificial currents, are also discussed. These include: uses of chemicals, sinking, air entrainment and entombment.

A generalized description of pier structures is also included. (EPA)

~~This report was submitted in partial fulfillment of Project 15080 FVP under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.~~

17a. Descriptors: *Oil Spills, *Oil Pollution, *Hydrulics, *Jets, *Piers, *Docks, *Boats, *Nozzles, *Emulsions, Entrainment, Pollution abatement, Water pollution control

17b. Identifiers: *Fire Departments, *Surface Currents, *Monitor Streams, *Hose Streams, Surface Collecting Agent

17c. COWRR Field & Group: ~~05~~ 05G

73-116

Copy available from GPO Sup Doc as ~~P1.23/2~~, $0.65; microfiche from NTIS as PB 221 545, $0.95.

18. Availability: ✓

19. Security Class. (Report)
20. Security Class. (Page)
21. No. of Pages 29
22. Price

Send To:
WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

Abstractor: Bernard Katz | Institution: Alpine Geophysical Assoc. Inc. for N.Y.F.D.

1a

EPA-R2-73-116
February 1973

REMOVAL OF OIL FROM UNDER PIERS

by

Bernard Katz

Project 15080 FVP

Project Officer:

Frank J. Freestone
Edison Water Quality Research Laboratories, NERC
Edison, New Jersey 08817

Prepared for

OFFICE OF RESEARCH AND MONITORING
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price 65 cents domestic postpaid or 45 cents GPO Bookstore

ib

EPA Review Notice

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessary reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

While this report deals primarily with methods of extracting oil from under piers, it is recognized that simple extraction is not enough, and that the oil should also be removed from the environment. Therefore, considerable attention has been paid to driving the oil out in such a way that it can be picked up. The primary means of extraction are by the establishment of artificial currents under the contaminated pier, and a number of methods are suggested to cope with various types of pier substructure.

Some other possible approaches, not involving flushing by artificial currents, are also discussed. These include: uses of chemicals, sinking, air entrainment and entombment.

A generalized description of pier structures is also included.

This report was submitted in partial fulfillment of Project 15080 FVP, under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.

CONTENTS

Section		Page
I	Conclusions	1
II	Introduction	3
III	Piers	5
IV	General Aspects of Oil Removal from Under Piers	7
V	Methods Not Requiring Artificial Currents	9
VI	Artificial Currents	11
VII	Fire Streams	13
VIII	Methods of Generating Under Pier Flow Using Fire Streams	15
IX	Methods of Applying Artificial Currents Under Piers	17
X	Acknowledgements	27
XI	References	29

Preceding page blank

FIGURES

Number		Page
1	Use of Under Pier Boom	18
2	Clearing a Cul-de-Sac	22
3	Drawing Oil Out of an Embayment by Entrainment	23

SECTION I

CONCLUSION

The methods described herein may be used to flush the area under almost any structure built over water and supported by piling, provided there is enough current generating capacity. Options other than flushing have also been suggested. However, for any of these methods, adaptations to particular situations will be required, and the on-scene coordinator should thoroughly familiarize himself with the details of the structure and the surrounding area. Also he should maintain a constant vigil to be sure that his operation is having the desired effect.

No operation that extracts oil from under a pier can be considered successful if most of the oil is not picked up, and all the suggested methods have been devised with this in mind.

SECTION II

INTRODUCTION

In any harbor there are likely to be numerous piling supported structures beneath which spilled oil will collect. These will be places where there is little or no flushing by the natural current, and usually they will be inaccessible to pick-up devices. There are several approaches to the problems posed by such oil; however, one should realize that oil under a pier is less destructive to the environment than the same oil would be if it were staining the shoreline, coating the bottom, or dispersed in or floating on the surface of open water. In short, unless the expelled oil can be contained and subsequently picked up, it is better to leave it under the pier. A quantity of oil seeped out over a long period of time will be less noxious than the same quantity released all at once. This does not mean that no attempt should be made to remove oil from under a pier; rather it means that efforts at containment and pick-up should take precedence over extraction. For this reason, although the main thrust of this study has been towards getting oil out from under piers, considerable attention has been paid to doing this in such a way that control and pick-up is possible. However, the use of containment and pick-up devices has not been treated in detail since these subjects are amply described in other manuals, and such treatment is beyond the scope of this one.

Preceding page blank

SECTION III

PIERS

Although piling does affect the flow of water and oil, in most cases this effect causes minor difficulties when compared with other problems encountered in removal of oil from under piers. The effect of piling becomes a relatively severe problem only: in the vicinity of specialized structures, such as ferry slips, where the spaces (if any) between piles are narrower than the piles themselves; when the oil is extremely viscous, such as bunker C in cold weather; or where there is a lot of floating debris that can clog the spaces between the piles. The main problems presented by piling arise from the fact that piling is almost always too dense to permit the maneuvering or manipulation of any reasonable sized equipment in its midst.

The most common type of pier substructure in New York Harbor consists of rows of piling which run transverse to the long axis of the pier, whether this long axis is perpendicular or parallel to the shore. The spacings between rows are from about 10 to 25 feet; between piles within a row the spacings average from about 1 to 5 feet. These spacings, of course, depend on the weight of the pier, the purpose for which it was designed, the structural material (wood, steel, concrete), and the thickness of supporting members. There are varying amounts of cross-bracing and cribbing between piles, but most of the more common pier types have some horizontal beams between piles that just clear the water at low tide and are submerged at high tide. Most often they run along a row of piles, but it is also common to find them stretched between rows. Pier corners, especially of piers built for the mooring of large ships and barges, are often very heavily constructed of thick clusters of adjacent piles. Also the ends of piers and often the sides too, are more heavily constructed than other parts. Many pier ends are faced with solid wood or metal sheathing. Under some piers the piles in a row tend to be grouped, with spaces between the piles in a group being about one foot, and spaces between groups being several feet. Many piers have fire walls underneath. Typically these: take the place of one or more of the transverse rows, are made of concrete, are supported by piles so that they extend down almost to the low tide water level, and are placed 120 to 150 feet apart.

Serious difficulties in the removal of oil from under piers can arise from one or more of the following factors:

(a) Large size with respect to the means available for generating water movement. One of the newer piers in New York Harbor covers 15 acres, and there are larger ones. Also there are many long stretches of roadway supported by piling.

(b) Limited accessibility because of shallow water, adjacent structures,

Preceding page blank

restricted channels, or moored vessels.

(c) Complex configuration; the plan views of many shore side installations exhibit varying degrees of complexity, from simple finger piers to intricate juxtapositions of platforms and wharves. The shoreward ends of many piers abut onto platforms or roadways which are themselves on piling, rather than onto solid bulkheads or shoreline. This provides additional places for oil to collect, as well as possible escape routes for oil during cleanup operations. Some pile-supported structures abut bulkheads on two or even three adjacent sides, thus forming covered pockets or embayments. In most places where oil is likely to collect, it will be impossible to establish a flow which goes directly through without some diversion.

(c) Low clearance; the under sides of many structures are below the water surface for part of the tidal cycle, and only a foot or so above it at other times.

In practice, any possible combination of these obstacles can arise. When coping with a particular set of problems, various types of equipment will be required. In general, the larger the pier, the larger will be the amount, size, and power of the equipment needed. Some structures are big enough to exceed the capabilities of the equipment presently available for driving the oil out. Thus, of the above difficulties, large size is the one that will prove the most intractable. While it will often be possible to clear a large area by dividing it into sections and doing one section at a time, in many cases it will not be possible.

SECTION IV

GENERAL ASPECTS OF OIL REMOVAL FROM UNDER PIERS

Because the buildings along a shoreline can vary so widely in size, substructure, accessibility and configuration, it is not possible to develop a set of standard procedures for cleaning oil out from under them. However, there are a number of general techniques that can be applied to a wide variety of situations. These are described below. Which to use will depend on the circumstance, and a proper selection will require a detailed knowledge of the area to be cleared. Therefore, the very first step should be to make a detailed examination of the pier's substructure from a small boat. Since the area under many piers, especially those where oil is likely to become trapped, is often very dark, powerful hand lanterns or flood lights will often be necessary for an adequate inspection. The need for such an inspection from a small boat cannot be stressed too strongly, because the details of the substructure must be known if the operation is to be effective, and these are often impossible to ascertain from the deck of a fire boat or tug boat, from shore, or from a neighboring pier. For example: For piers running parallel to and abutting with a bulkhead it is necessary to know the distance between the bulkhead and the outer edge. It is important to know if there is cross bracing in the path of any proposed flow. Fire wall ends are often recessed from the pier edge, and cannot be seen by an observer who is not at the edge of the pier and well below the platform level. Conversely, there are supports along some pier edges which, at a short distance, appear to be the ends of fire walls; that they are not can only be determined from closer inspection. Since we are concerned here with trapped oil, that is, oil which is not rapidly escaping or spreading, there is less need for haste, and we can take advantage of this fact to plan a more effective operation from the start.

There are three phases to any successful removal operation: Extraction, containment, and pick-up.

Pick-up involves the use of some sort of skimmer, and is relatively straightforward. Except in rare cases where the piling is very open, the only oil that can be picked up will be that which has been extracted from under the pier and contained by boom. There are a number of skimmers on the market. For all of them the efficiency of their operation depends on the concentration of oil in their vicinity. Hence the arrangement of boom and skimmer should be such that oil will tend to concentrate around the pick-up point. In practice, this means that the skimmer should be located as close as possible to a corner or apex towards which the flow is established.

Boom performs a dual function. It not only prevents the escape of oil driven from under a pier, but it also must channel this oil towards the pick-up device. Sometimes boom can be used to keep a

cleared area from becoming recontaminated. In general this requires that the boom be deployed under the structure, and will only be possible where:

(a) There is enough overhead clearance and space between piles to allow passage of a small boat. (A two-man rubber raft can be used.)

(b) There are no cross braces in the way.

(c) There is no current to force the boom hard up against a row of piles.

For use in this way a boom having "internal" flotation is better than one having detachable flotation, since it is less likely to snag. Where the emergent flow is intercepted by the boom, its velocity should be less than a half knot (it can be slightly higher where the flow is not perpendicular to the boom), because larger velocities will cause oil to be carried under the boom. In any case there is no need for the emergent flow to have a large velocity. A slow, barely perceptible drift into a gradually narrowing corner or pocket will deliver all the oil that most skimmers can effectively handle. For example: One small but effective vacuum type skimmer picks up fluid at a rate of 1.5 ft^3/min. The percentage of oil in this depends on the thickness of the oil layer under the suction mouth. (The pickup rate is 15 ft^3/min if the mouth is completely immersed, but it cannot be used in this way unless the oil layer is a few inches thick.) A 50 ft wide oil slick, one tenth of an inch thick, being channelled towards a pocket where this skimmer is operating need move at only 0.04 knots to keep this skimmer well supplied.

SECTION V

METHODS NOT REQUIRING ARTIFICIAL CURRENT

The main approach to the problem of oil trapped under piers is flushing with artificial currents, but before discussing this, there are several other options that deserve mention:

Strong air flow would be capable of dragging oil from under a pier. It has an advantage over artificial water currents in that it would produce very little turbulence and would thus cause very little mechanical emulsification of the oil. In addition to a large wind generator, heavy curtains might be required in most cases to channel the air flow, and boom and skimmers would still be required to channel and remove the oil. The necessary equipment is probably unavailable in most harbors; therefore, this method is not one suitable for general use.

Chemical solvents or dispersants would remove oil from under a pier, and their application would be relatively easy. But the oil and chemical would soon spread in substantial concentration through a sizable volume of nearby water. The damage to the environment would be increased rather than reduced. Even though some of the recently developed dispersants are practically non-toxic, the oil would still retain most of its harmful properties which are better restricted to the area under the pier or they cannot be removed entirely. Therefore, this method is the least acceptable of all, and would be illegal in many cases.

It is also possible to sink the oil. This method is worthy of consideration because the sediment under most piers, especially in commercially active areas, is already badly contaminated, and further damage to this relatively small and useless area might be preferable to the damage wrought by the same oil elsewhere. A similar approach is "entombment" of the oil by enclosing it with sheathing. Though this may seem like doing it the hard way, the fact is that in many cases it will be no harder or more time consuming than extraction and pick-up of the oil. The sheathing need not extend from the pier's deck down to the sediment; a few feet above high water level to a few feet below water level would be enough. There would be a bonus in that the sheathing would protect the area from contamination by subsequent spills in the vicinity. While it is true that "entombed" oil may eventually seep out, and sunken oil will dissociate and disperse, this will take a relatively long time, during which there will be the opportunity for biodegradation of the oil; a process which can be enhanced by seeding with the proper type of organisms and aeration of the water under the pier.

Under certain conditions, a chemical surface collecting agent (SCA) can be used to move oil from beneath a pier. Surface collecting

agents are substances which reverse the tendency of most oil to spread on water, and instead cause the patches to contract and form "lenses". They do this by changing the surface tension balance.

To remove oil from under a pier, the SCA must displace the oil rather than cause it to contract. This can be accomplished only if the SCA is restricted to one side of the oil slick. Once the SCA completely surrounds the oil patch, there is no longer a difference in spreading force on either side, and it can no longer produce any displacement. Since SCA spreads far more quickly than most petroleum products that are likely to require removal, it is important that there be no path through the oil slick or along its edges by means of which the SCA can spread to the outer side. In practice this means that SCA can only be used for flushing when there is a continuous sheet of oil covering an embayment or cul-de-sac from wall to wall. The SCA must be placed in the deepest corner or against the farthest wall. Unless there is an access hole properly located this will require that a small boat be taken under the pier for placement of the SCA. It should not be poured directly onto the oil. Rather a small patch of water must be cleared into which the SCA is poured. This can best be done by vertically agitating a plunger (a small plate attached to the end of a pole so that it is perpendicular to the pole's axis) in the water near the surface.

This work with surface collecting agents has been limited to laboratory experiments and tests made on small spills of opportunity. These have not enabled a determination of the quantitites of SCA needed to achieve various displacements with different types of oil. However, the amounts needed will be small because the SCA need only spread in a very thin layer. For open water the prescribed dosage is two gallons per linear mile of oil patch circumference. SCAs do not work on thick, waxy oils such as Bunker C, or in waters having a high concentration of detergent. Some of them are also ineffective in cold weather. While wind and currents can interfere with the action of an SCA, this is not likely to be a problem in the under-pier areas where oil collects.

The use of surface collecting agents, dispersants, and sinkants is now strictly regulated and they can only be used when so authorized by the On Scene Coordinator (OSC). Entombment of the oil also requires OSC approval since regulations now require that the oil be removed from the water as quickly as possible.

SECTION VI

ARTIFICIAL CURRENTS

The primary tools for extracting oil from beneath piers are artificial water currents. There are two common means of generating these: Fire streams and propwash. The different methods of generation produce currents with slightly different characteristics: The first, of course, is size. A boat's propellers are far more efficient generators of water movement than its pumps, even when they are powered by the same engines. The second is shape. A fire stream's induced current spreads about 80 degrees from the impact point of the stream. The current pattern produced by propellers has a much smaller angle of spread, only 5 to 10 degrees, though it is much wider to start with. The third difference is in the nature of the turbulence. Propellers produce larger eddies than streams of water even when the energy outputs are comparable. And propeller turbulence has a much stronger vertical component which extends much deeper. This is important because turbulence causes mechanical emulsification of the oil, and the large deep eddies can drag the oil droplets down well below the skirt depth of even the largest boom. These droplets have a natural tendency to rise, and will begin to do so as soon as the turbulence subsides; however, the smaller droplets rise very slowly. Thus, while it is possible to contain much of the oil set in motion by propwash if the containment boom is located far enough from the propellers, a substantial portion inevitably escapes. For this reason, the use of propwash should be limited to these situations where fire streams are clearly inadequate, or where no fire streams are available.

Despite these differences, the methods of applying artificial currents are essentially the same whether they are generated by fire streams or propellers. However, fire streams are much easier to position and control. In both cases, the boat must be moored, but the mooring required for fire stream operation is much lighter and hence more adaptable. Also monitors can be aimed, whereas to direct propwash the entire boat must turn, and this will not always be possible.

While it is true in any clean-up operation that the coordinator should constantly observe the effect of the various measures being employed, it is even more important when using induced currents, because slight changes in the parameters of the operation can change it from an effective one to an unproductive, or even a counter productive one. For example: A change in the wind can alter the impact point and/or the strength of the fire stream; it can also affect the flow of oil and the configuration of the boom array. Though we are concerned with areas where the natural currents are virtually nil, they could still be an important, though erratic and unpredictable, factor. It takes time for an induced current pattern to stabilize, and a

procedure that has been working well initially may become unsatisfactory when fully developed. The rise and fall of the tide can open or close channels. In short the coordinator should repeatedly assure himself that the effects of his operations are the ones he desires.

SECTION VII

FIRE STREAMS

In using fire streams at an oil spill, it is important to realize that it is not the fire stream itself which controls or moves the oil, but the current set up by it. In fact the fire stream should not be allowed to impact on, or very close to the oil because, if it does, the oil will be emulsified. To minimize this the impact zone should be kept at least 50 feet from the oil slick when using large caliber, high pressure streams. For under pier work, the distance over which a fire stream generated current is effective depends very much on how it is used as well as on its output. But effective flow can generally be achieved a few hundred feet from the impact zone. Though fire streams have produced useful oil movement at distances of about a thousand feet, this was under ideal conditions, and such ranges cannot be expected in general.

For purposes of controlling oil slicks, the useful output of a fire stream is its continuous discharge of momentum. This momentum discharge--the time rate of momentum output--is proportional to the product of the nozzle tip area and tip pressure (velocity head). It is, in fact, equal in magnitude, but opposite in direction, to the reaction force on the nozzle. Unfortunately, the entire momentum output of the tip is not usable. There are two reasons for this:

a) The fire stream usually enters the water at an angle. Therefore, it has a horizontal and a vertical component. Only the horizontal component is useful for the control of floating oil. The smaller the angle of entry, the larger the horizontal component will be. Decreasing the height of the tip, and increasing the pressure have the effect of reducing the angle of entry. For any particular height and pressure the angle will be the smallest when the tip is aimed horizontally, and will increase as the angle between the nozzle and the horizontal (whether elevation or depression) increases.

b) A portion of fire stream's momentum is lost to air resistance. Although the process by which this happens is not fully understood, it is known that, with the same pressure, air resistance increases with increasing tip size and, with the same tip, air resistance increases, at an even faster rate, with increasing pressure.[1] Also droplets are much more affected by air resistance than solid streams, and the smaller the droplets the more they are affected. Thus nozzles which tend to break up the fire stream into fog or fine spray are generally ineffective. By the same token, solid streams should be operated at pressures well below those at which coning occurs.

Of course, the longer the fire stream, the greater the effects of air resistance. Thus, while the smallest angle of entry is achieved when the nozzle is aimed horizontally, a slight downward angle of aim

would shorten the fire stream, and the increase of momentum loss due to increased angle of entry would tend to be offset by the decreased loss due to the shorter fire stream. On the other hand, an upward angle of aim increases the fire stream length and the air resistance loss as well as increasing the angle of entry. Thus, depressing the tip from horizontal by several degrees will have little effect, but elevation from the horizontal produces rapid deterioration.

The fire stream establishes a fan-shaped current structure spreading about 80 degrees from the impact zone. If this current structure has components directed opposite to the natural current, a turbulent rip zone will develop at its upstream edge. The distance from the impact point and width of the "front" covered by the rip zone increase as the horizontal momentum input to the water increases, and as the natural current velocity decreases. In open water the net flow in the rip zone is tangential to it and directed away from a horizontal axis drawn parallel to the fire stream. But, when confined in a channel so that the rip zone extends across the entire width of the channel, there is no net flow in the rip and it becomes a null current zone.

If the natural current is small, less than one half knot, the turbulence of the rip zone is not intense, and it will be a barrier to floating oil. Under these conditions the zone can be used to block or direct the flow of oil. In general, this will be accomplished by directing the fire stream in the direction of desired oil movement.

If the natural current is large, the turbulence of the rip zone will be intense, and it will not be a barrier to floating oil. Under these conditions, the fire stream may only be used to divert the oil, usually by directing the stream at right angles to the direction of the natural current. While these principles are generally applicable, the majority of cases where it is necessary to apply artificial currents to remove oil from under a pier will require a diversion of the current because a direct path between the source and the possible exits for the oil will be impossible.

For a somewhat more detailed discussion of the use of fire streams in oil spills see reference (2).

SECTION VIII

METHODS OF GENERATING UNDER PIER FLOW USING FIRE STREAMS

Once it has been determined to use artificial currents to flush an under pier area, the two immediate problems are: How to establish the flow, and where and in what direction to establish it. The latter depends on the configuration of the area and will be discussed subsequently.

The simplest way to establish a current is by mooring the boat to an adjacent structure in a way that will permit its fire streams (or propwash) to be directed as needed to set up the desired flow. Unfortunately, it will often be impossible to find a suitable mooring. The adjacent pier, if any, may be poorly oriented or too far away. Though the impact zone does not have to be--and in most cases should not be--at the edge of or under the pier being flushed, the fire stream may not be able to span the distance with enough reserve momentum to establish a sufficient flow. A fire stream's range depends mainly on tip pressure and elevation. For any pressure the range can be increased, up to a point, by elevating the tip from the horizontal. But, if the angle of elevation exceeds several degrees, the effectiveness of the stream as a current generator suffers. For a 3-inch tip operating at 150 psi the maximum distance between the tip and the impact zone, consistent with the generation of an effective flow, is about 130 feet. In the absence of any natural current this will produce an effective flow extending about 300 feet from the impact zone. Thus, under nearly ideal conditions we can expect to move oil at a distance of about 430 feet from the monitor. The presence of even a slight wind or a miniscule current from any direction except behind the monitor will substantially reduce this distance.

Where it is not possible to operate effectively from an adjacent pier, it may be possible to moor directly to the contaminated pier. If the fire streams are to be directed perpendicular to, or at a large angle to the pier edge, the boat must be held 50 to 100 feet away from the edge with long mooring lines. The reaction force on the monitors will be sufficient to hold the boat out, but it may be necessary to use the engines and rudder to compensate for yaw. If only the bow monitor is used in conjunction with a single bow mooring line, the thrust of the reaction force and the pull of the mooring line will tend to assume the same line of action, and the mooring line may get in the way of the fire stream. Two mooring lines to separate ballards or cleats, with the fire stream directed between them, will avoid this. Fore and aft mooring, with the boat parallel to the pier edge, will permit the use of additional monitors and also of rail pipes.

If under pier pipes are available, the fire boat can be moored close to the pier. Since the nozzle is now at the edge of the pier

it should, in general, be as close to the water surface as possible. However, if the pier is large and the oil has receded from the edge of the pier, the impact zone can be advanced by elevating the tip. For some applications it would be better to have the tip at, or slightly below the surface; these are described in a later section.

Use of hand held hose lines from small boats is the most versatile method of generating flow under piers. It involves more effort, but it can be used in many situations where other methods cannot, such as: where there is no suitable mooring near enough; where the fire boat cannot approach the pier because of obstructions or shallow water; where (if the piling is not too dense) it is desirable to establish the current deep under a large or complex pier. The only limitation is the amount of hose available. If stand pipes or land pumpers are available, it is not even necessary to have a fire boat present.

Because the effectiveness of the streams depends so much on the discharge, the largest hose, tip, and pressure consistent with safe operation should be used. We have used a 2-1/2 inch hose with a 1-1/4 inch tip operating at 60 psi tip pressure without any difficulty. However, when in operation both the tip and the small boat will have to be secured. The boat should be secured sideways between piles by fore and aft painters. The tip, operating between the piles, can be secured by one or more hose straps or pieces of line. Reaction force on the tip will be about 150 pounds (1-1/4 inch tip at 60 psi). If the boats gunwale is fairly sturdy, the hose strap can be hooked directly to it. The line or hose strap may also be attached to parts of pier's substructure, but, if attached to piles, two lines to separate piles will be needed. In all cases the attachment of the line to the hose should be far enough behind the tip so that the tip is just outboard of the gunwale.

The hose must be floated. If the hose is not to be taken under the pier, or if the pier's substructure is free of subsurface snags, several large floats are adequate and quicker to attach. But in most cases, it is better to use smaller floats more closely spaced. Quart size floats with 3 to 4 foot spacings and an additional float at the brass coupling supported the 2-1/2 inch hose very well. To further reduce the possibility of snagging, the floats should be attached with their long axis parallel to that of the hose. This can be done with friction tape or with string; there appears to be no reason to prefer one over the other. Because it is so much easier to handle uncharged hose, it is better to affix the floats and play out the hose before applying pressure. However, most fire hose is flat when uncharged and round when charged, and the method of affixing the floats must be able to accomodate the change in dimension. With string this is done by first tying the string around the hose using a square knot and leaving ends long enough to encircle the float and tie another square knot. With tape, make a figure "8", lashing with alternate clockwise turns around the hose and counter clockwise turns around the float (or visa versa) and finish with a few turns around the tape intersection between the hose and the float.

SECTION IX

METHODS OF APPLYING ARTIFICIAL CURRENTS UNDER PIERS

Longitudinal Flushing

If it is possible to do so, the best way to flush the area under a pier is to establish a flow perpendicular to the pier's long axis. Attempts to generate a current down the length of the pier will generally be far more difficult and far less effective. There are two reasons for this. The preferred direction of flow is parallel to the rows of piles, and these run perpendicular to the long axis for almost all piers. This is not so much because of piles themselves as it is because of the cross-bracing, which is much more dense in a row than it is between rows. Many piers have fire walls underneath; these almost always run perpendicular to the long axis of the pier, and would permit longitudinal flushing only at dead low water. Second, even with fairly open piling, most piers are too long. Pier lengths well over 600 ft are common, while the effectiveness of fire stream generated currents usually vanishes between 300 and 400 feet from the impact zone for the larger monitors. Propwash may be capable of longitudinal flushing under long piers which do not have transverse fire walls. In using propwash, the thrust of the propellers should be at an absolute minimum initially, and gradually increased as the edge of the oil recedes down the length of the pier.

For longitudinal flushing, boom should be deployed along both sides of the pier. The far end is assumed to be closed by a bulkhead or shoreline (if not it will have to be boomed) and the skimmer is located in one of the far corners. In the final stages of the operation, smaller streams from hand lines will be useful in channeling the remaining oil to the skimmer.

Transverse Flushing

Since currents generated artificially by boats have effective widths from about twenty to about 200 feet (depending on how they are used and how they are generated), while pier lengths often exceed 600 feet, flushing under a pier with transverse currents will almost always be a piecemeal task. The essentials of the operation are as follows: The current is generated on one side of the pier, and the boom and skimmer array is situated on the opposite side so as to intercept, concentrate, and pick up the emerging oil. After a section has been cleared, the current generator on one side, and the boom and skimmer on the other side are moved down to the next section. When proceeding in this way, it is necessary to prevent the section just cleared from becoming recontaminated. If the artificial current is broad, this is

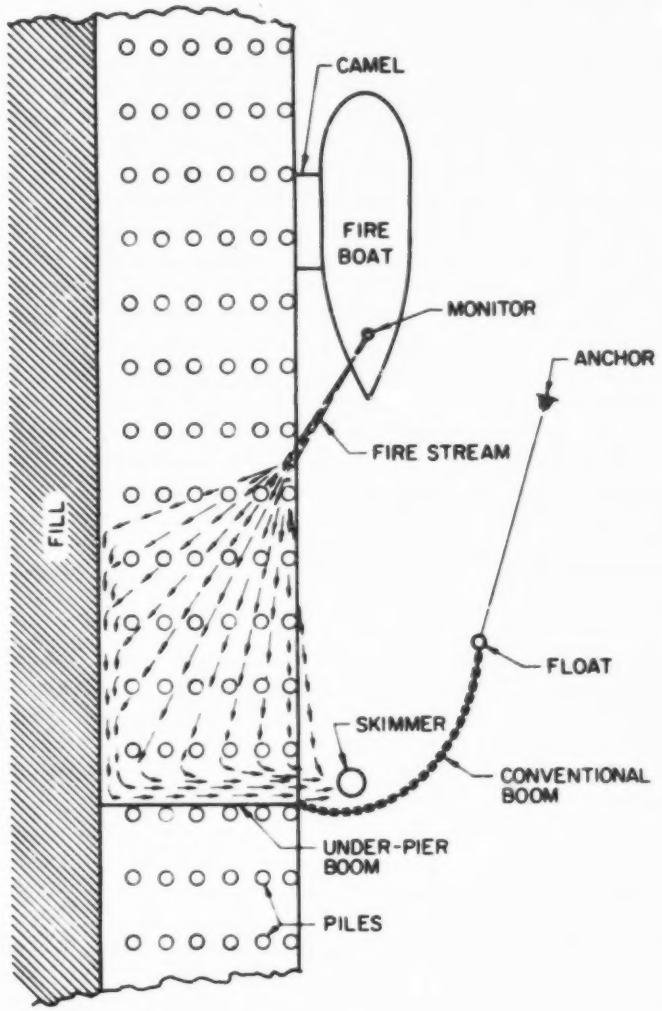

FIGURE 1

USE OF UNDER PIER BOOM

accomplished by making each section about half the width of the current. If the current is not wide, it will be necessary to operate an auxiliary current in the section just cleared. The rows of piles do inhibit broadening of the induced flow; therefore, if the flow is being generated at the edge of the pier by under pier pipes or hand lines, it will generally be possible to clear only one aisle at a time. However, if a large monitor impacting about 30 to 50 feet from the edge of the pier is used, the artificial current will effectively span three or four aisles before it goes under the pier. If it is possible for a small boat to pass under the pier between rows of piling, boom may be deployed to protect the cleared sections.

The collection boom will "belly" away from the pier, with the apex of the belly near the strongest part of the emergent flow. If only one current generator is used, the apex will be roughly opposite the generator, if two are used, it will be opposite a point between them. The array should be adjusted so that the skimmer is as close as possible to the apex. If the emerging oil tends to collect uniformly along the boom rather than being channelled towards the apex, the belly should be deepened by slacking the boom. To deepen the belly it may prove necessary to hold the boom and skimmer out by means of a line to a nearby structure or to an anchored float. If, for some reason, it is not possible to obtain a deep enough belly, small hose lines can be used to establish a flow along the inside of the boom towards the skimmer. In this case it will be easier to locate the skimmer more to one side of the boom array, establishing as much of a pocket there as possible, and operate the hand line from the other side.

The procedures just described are suitable for a pier much longer than it is wide, having bulkhead or shoreline on one or both ends, and open water on both sides. Such piers are comparatively easy to flush out because it is possible to establish a direct flow entering on one side and emerging on the other. Since most such piers extend into a channel where there is a natural current, oil will not usually become trapped under them except near the shoreward end. In general, a pier under which an artificial flow can be easily established will be subject to flushing by natural currents. Conversely, piers not subject to natural flushing, those under which oil is prone to collect, will be the most difficult to clear. The following procedures have been developed for such cases.

Under Pier Boom

Many piers and over-water roadways run parallel to and abut with a shore line or bulkhead. The only possible exit for a flow directed under such a structure is on the same side as the entrance, but any flow so directed will tend to move along under the structure, with most of the energy concentrated along the

bulkhead, or inner edge and very little emerging. In the absence of fire walls, it will be necessary to insert a barrier that will deflect the flow outwards. If there is enough clearance for a small boat, conventional boom can be used, but in many instances the clearance, even at low tide, will be too small. To overcome this problem we have constructed boom using boards with lead weights for ballast and small floats for buoyancy. These are bolted together, with wing nuts and preset bolts, and pushed under the pier. The assembly and positioning is done with the boom in the water by a man in a small boat, which must be moored to one of the piles. As each section is added, the boom is extended further under the pier. Up to 28 ft of this boom has been assembled with relative ease, and greater lengths are evidently possible. To accomplish its task, the boom should extend all the way across the pier from the bulkhead on one side to the outermost piles on the other. The outer end of this boom is matched with any type of conventional boom which is then extended out towards mid-stream and back toward the current generator, and secured to an anchored float. The plank boom is braced against the applied current by a row of piles, and it should be tied to the outermost of these piles in such a way that it can rise or fall with the tide.

The artificial flow should be directed at about a 45 degree angle under the structure and towards the boom. (Figure 1) To achieve an effective angularity along with an effective stream velocity, it may be necessary to hold the fire boat away from the pier. This can best be done by mooring a floating fender (a camel), or another boat between the pier and the fire boat. The boom and the current generator (or impact zone of the fire stream for deck monitors) should be far enough apart so that the axis of the current is intercepted by the bulkhead well before it reaches the boom. This means that the wider the pier (i.e. the greater the distance between the outer edge of the pier and the shoreline or bulkhead) the greater must be the distance between the current generator and the under pier boom. The objective is to create a flow under the pier along the closed inner edge which is deflected outwards by the under pier boom. The speed of the current when it reaches, and is diverted by the boom, should be less than a half knot. The ultimate configuration of the boom array will depend on the width and strength of the current, the width of the structure, and the angle of entry of the current. However, the flexible boom attached to the under pier boom will form a belly in response to the flow, and the skimmer should be located at its apex. Since each situation is likely to have its own characteristics, on scene experimentation will probably be necessary to achieve optimum results.

The under pier boom can be constructed of any material having enough rigidity to enable it to be pushed under a pier. The prototype was made of 10 ft x 1 ft x 1 inch pine boards, with 12 lbs of ballast along one edge, and two quart-size plastic bottles for flotation. The boom had about 4 inches of freeboard and 8 inches of skirt. For

strength there was one foot of overlap where the planks were joined with four bolts and wing nuts backed by large washers. Because of its rigidity, the under pier boom will not conform with the water surface as waves pass; however, it is designed for use in places where waves of more than a few inches height will only be an occasional problem. If more freeboard or skirt is needed, broader planks can be used.

Cul-de-Sacs

The substructures under many shoreside installations form basins or cul-de-sacs having three sides closed and only one side open. For example: A long pier or roadway running parallel to and abutting with bulkhead, as described above, and also having transverse fire walls, will form a series of such covered embayments. The bulkheads are capable of diverting a flow outwards, so under pier boom is not needed. But, because distance between the sides of the basin is usually not much greater than the distance between the mouth and the closed end, a different type of current structure must be established. Instead of directing the current inwards, and at an angle towards the bulkhead which is to deflect it outwards, we try to establish a rotary flow entering along one side and emerging along the other (Figure 2).

In establishing such a flow it is important that the current enter only one side of the basin, leaving room on the other side for an emergent flow. When using deck monitors, the fire streams should be aimed as though the entering current were required to bounce off one wall of the basin. If it is aimed too directly into the basin, even though the impact zone is near one side of the basin's mouth, the large angle of spread of the current could cause it to span the entire width of the basin before it reaches the closed end; and the only effect would be to drive the oil deeper into the basin. Aiming the fire stream in this manner will cause a part of the induced current to be wasted, since not all of it will be intercepted by the wall and channelled into the basin. The further the impact zone from the mouth of the basin the greater will be the proportion of the momentum flux that is lost in this way, but it should never exceed fifty percent, since the line of aim should be into the basin's mouth. Aiming the stream more towards the center will reduce this loss, but, unless the basin is very wide or the impact point quite close to the mouth, this loss cannot be eliminated completely without destroying the rotary flow. However, the loss of momentum flux does not appear to present a serious problem. We were able to achieve the desired results in a 200 x 160 ft cul-de-sac, using a 5 inch tip, operating at 75 psi, and impacting 60 ft from the mouth of the basin with only about 60% of the flow entering it. If necessary the loss could have been reduced by advancing the impact zone along the same line of aim. Under pier pipes and hand lines from small boats can also be used to establish a rotary flow. Since they are operated

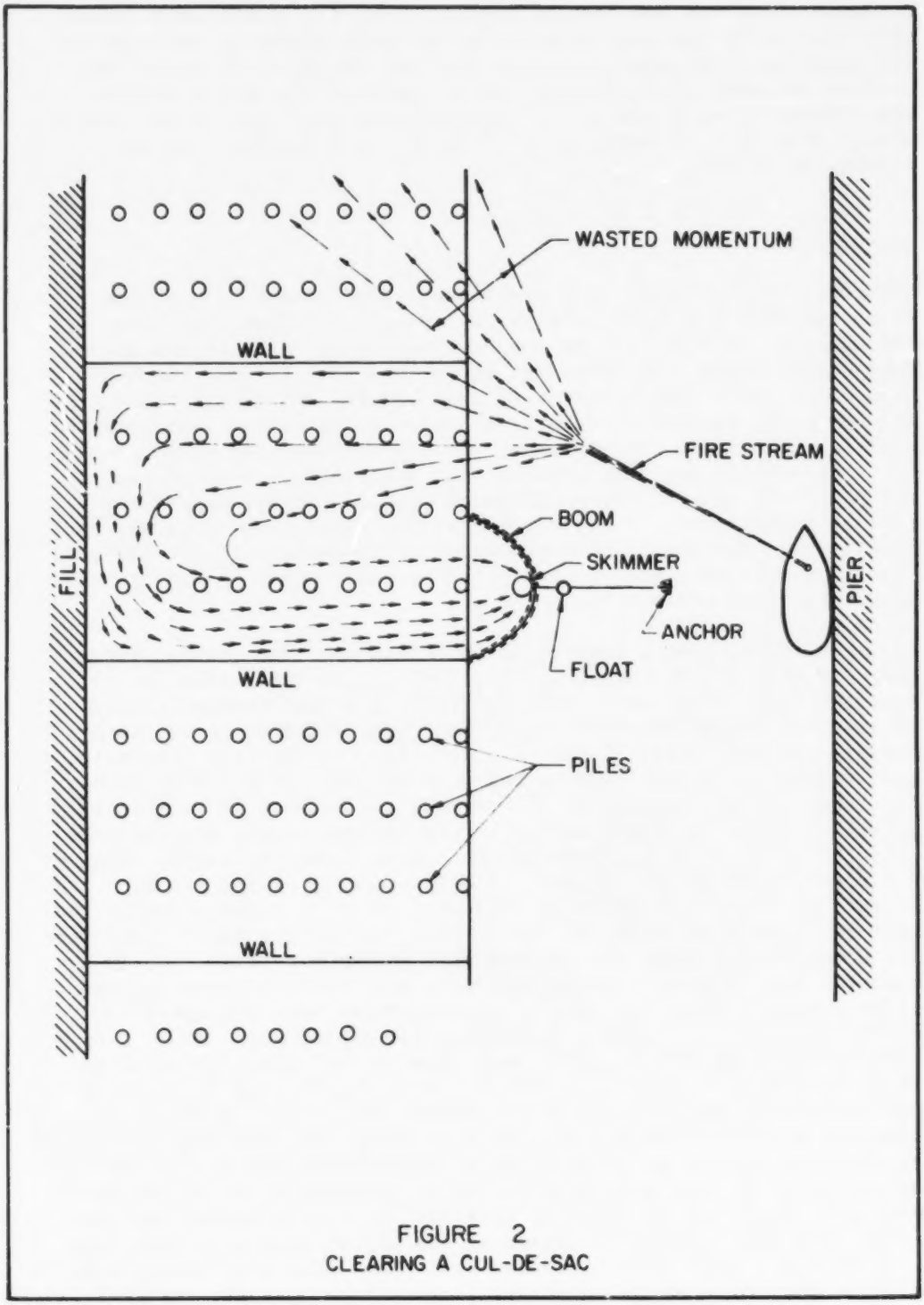

FIGURE 2
CLEARING A CUL-DE-SAC

close to the edge of the pier and the lateral spread of their induced flow is inhibited by the rows of piling, they can be aimed directly into the basin along one wall. However, since their output is so much smaller than that of monitors, it may be necessary to use two or more streams, parallel and close to each other, to achieve the desired flow. The boom must be deployed so as to intercept the emergent flow without interfering with the entering flow. This will be easier to accomplish when the current generators are close to the pier edge. The ends of the boom can be secured to piles at the edge of the pier, and the central portion, where the skimmer is to be located, should be held away from the pier by an anchored float so that the entire array forms a deep pocket.

If the basin is very narrow and fairly deep, with walls extending to the bottom (in effect a closed channel) it may be possible to set up a vertical rotary flow. To do this an under pier pipe with the tip submerged is used, and it is aimed into the basin at a downward angle, so that the current flows inward along the bottom and outwards near the surface. This is likely to stir up and flush out quite a bit of silt as well as oil. Since the mouth of the channel is narrow, the boom and current generator must be placed in tandem; therefore the tip should be well below the skirt depth of the boom. There are two possibilities; if there is a convenient hose hole or a means of securing the under pier pipe to the pier edge, the boom and skimmer can be placed outboard of the tip. If this is not possible, the ends of the boom will have to be fastened to the walls of the basin far enough under the pier so that the boom forms a deep pocket with its apex under the edge of the pier. (It may be necessary to drive studs for securing the boom ends.) The under pier pipe can then be operated from the rail of a boat moored across the mouth of the channel so that its stream passes under the boom. So far this method has only been attempted on a laboratory scale, and the limits of its effectiveness are not known.

Entrainment

A current moving through a body of water will drag some of the surrounding water with it. This process, entrainment, can be used to set up a flow of surface water out of a small basin by establishing a surface flow across the mouth of the basin. (Figure 3) On the whole this method is far less effective than the methods described above, but it might be useful in some situations. Since the outflowing surface water must be replaced, and in the case of a basin it is replaced by in-flowing bottom water, propwash, because of its depth, is not suitable unless the basin is very deep. Because of the large angle of spread of currents generated by deck monitors, it may be difficult to prevent a portion of the entraining current from entering the basin and setting up a rotary surface flow. But it will not be an efficient rotary flow, since much of the entrained, emerging water will be recirculated back into the basin. This difficulty can be reduced by keeping the tip as close as possible

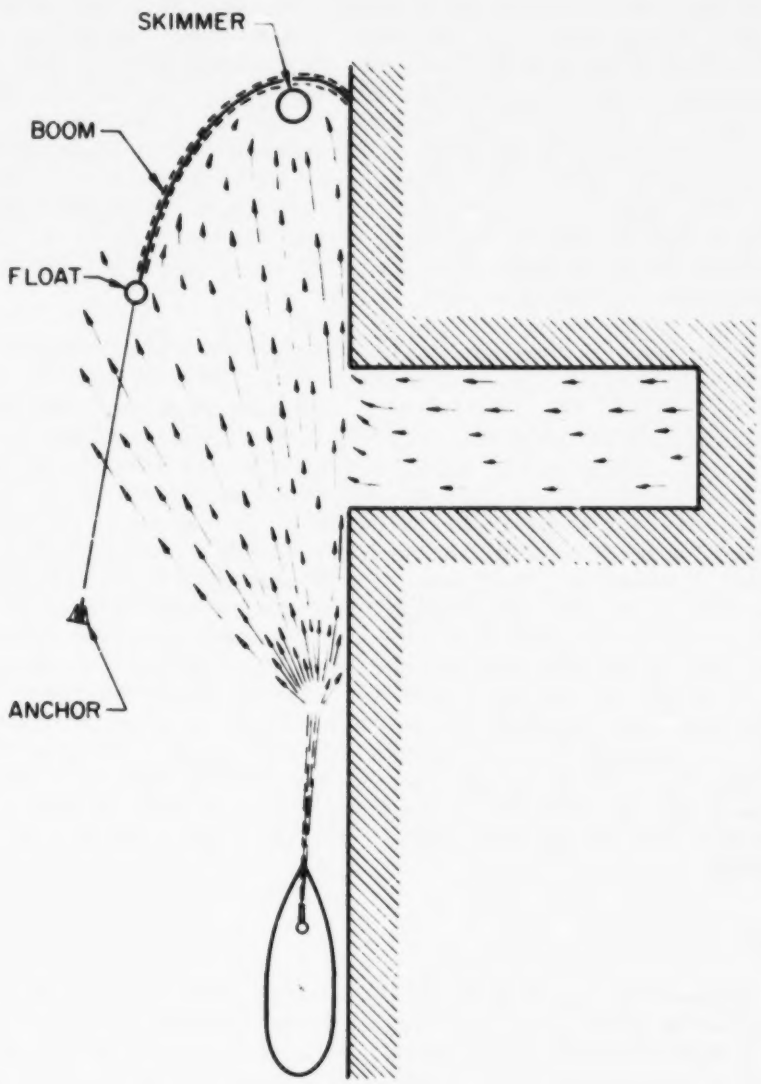

FIGURE 3
DRAWING OIL OUT OF AN EMBAYMENT BY ENTRAINMENT

to the surface. To create a significant flow out of the basin the entraining current must be quite strong. For this reason the size of the area that can be cleared by entrainment is limited; the maximum being about 100 ft on a side. Finally since the emerging flow becomes a part of the much higher velocity and more turbulent entraining current, the oil is subject to severe emulsification. For successful containment and pick-up the boom must not intercept the entraining current until it has become very weak, i.e. less than 1/2 knot.

SECTION X

ACKNOWLEDGMENTS

The practical use of fire boats and other apparatus at actual spills at numerous test exercises provided the basic information for this report. The Officers and Members of the Marine Division of the NYFD and the personnel of Alpine Geophysical Associates were the principal project participants.

The guidance of Mr. Frank Freestone, EPA Project Officer, and the cooperation of the City of New York and the U. S. Navy in providing the test basin at Wallabout Creek, Brooklyn, New York, is gratefully acknowledged.

Preceding page blank

SECTION XI

REFERENCES

(1) Casey, James F. (1970) Fire Service Hydraulics Reuben H. Donnelly Corp., N.Y.C., 427 pp.

(2) Katz, B. and Cross, R. (unpublished report) "Use of Fire Streams to Control Floating Oil" submitted to the Water Quality Office, EPA, by NYFD, December, 1971.

U. S. GOVERNMENT PRINTING OFFICE : 1973—514-153/218

Preceding page blank